Claims

What is claimed:

1. A semiconductor device, comprising:

a drain electrode;

a source electrode;

a channel contacting the drain electrode and the source electrode, wherein the channel includes one or more compounds of the formula $A_xB_xC_xO_x$, wherein each A is selected from the group of Zn, Cd, each B is selected from the group of Ga, In, each C is selected from the group Ge, Sn, Pb, each O is atomic oxygen, each x is independently a non-zero integer, and each of A, B, and C are different; and

a gate dielectric positioned between the gate electrode and the channel.

2. The semiconductor device of claim 1, wherein the one or more compounds of the formula $A_xB_xC_xO_x$ includes a ratio of A:B:C, wherein A, B, and C are each in a range of about 0.025 to about 0.95.

3. The semiconductor device of claim 1, wherein the one or more compounds of the formula $A_xB_xC_xO_x$ includes Dx, to form a compound of the formula $A_xB_xC_xD_xO_x$, wherein each D is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, and D are different.

4. The semiconductor device of claim 3, wherein the one or more compounds of the formula $A_xB_xC_xD_xO_x$ includes a ratio of A:B:C:D, wherein A, B, C, and D are each in a range of about 0.017 to about 0.95.

5. The semiconductor device of claim 3, wherein the one or more compounds of formula $A_xB_xC_xD_xO_x$ includes E_x, to form a compound of the formula $A_xB_xC_xD_xE_xO_x$, wherein each E is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, D, and E are different.

6. The semiconductor device of claim 5, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xO_x$ includes a ratio of A:B:C:D:E, wherein A, B, C, D, and E are each in a range of about 0.013 to about 0.95.

7. The semiconductor device of claim 5, wherein the one or more compounds of formula $A_xB_xC_xD_xE_xO_x$ includes F_x, to form a compound of the formula $A_xB_xC_xD_xE_xF_xO_x$, wherein each F is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb,, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, and F are different.

8. The semiconductor device of claim 7, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xF_xO_x$ includes a ratio of A:B:C:D:E:F, wherein A, B, C, D, E, and F are each in a range of about 0.01 to about 0.95.

9. The semiconductor device of claim 7, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xF_xO_x$, includes G_x, to form a compound of the formula $A_xB_xC_xD_xE_xF_xG_xO_x$, wherein each G is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb,, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, F, and G are different.

10. The semiconductor device of claim 9, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xF_xG_xO_x$ includes a ratio of A:B:C:D:E:F:G, wherein A, B, C, D, E, F, and G are each in a range of about 0.0085 to about 0.95.

11. The semiconductor device of claim 1, wherein the channel includes one of an amorphous form, a single-phase crystalline form, and a mixed-phase crystalline form.

12. A semiconductor device, comprising:
a drain electrode;
a source electrode;

means for a channel to electrically couple the drain electrode and the source electrode; and

a gate electrode separated from the channel by a gate dielectric.

13. The semiconductor device of claim 12, wherein the means for a channel includes a means for forming one of an amorphous form, a single-phase crystalline form, and a mixed-phase crystalline form.

14. The semiconductor device of claim 12, wherein the source, drain, and gate electrodes include a substantially transparent material.

15. A method of forming a channel, comprising:

providing at least one precursor composition including one or more precursor compounds that include A_x, one or more precursor compounds that include B_x, and one or more precursor compounds that include C_x, wherein each A is selected from the group of Zn, Cd, each B is selected from the group of Ga, In, each C is selected from the group Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, and C are different; and

depositing the channel including the precursor composition to form a multicomponent oxide from the precursor composition to electrically couple a drain electrode and a source electrode.

16. The method of claim 15, including providing a substrate or substrate assembly; and

forming the semiconductor device on the substrate or substrate assembly.

17. The method of claim 15, wherein depositing the channel includes depositing one of an amorphous form, a single-phase crystalline form, and a mixed-phase crystalline form.

18. The method of claim 15, wherein the precursor composition includes a liquid form.

19. The method of claim 18, wherein depositing the channel includes an ink-jet deposition technique when the precursor composition includes the liquid form.

20. The method of claim 15, wherein the one or more precursor compounds includes one or more precursor compounds that include D_x, wherein each D is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb each x is independently a non-zero integer, and wherein each of A, B, C, and D are different.

21. The method of claim 20, wherein the one or more precursor compounds includes one or more precursor compounds that include E_x, wherein each E is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb each x is independently a non-zero integer, and wherein each of A, B, C, D, and E are different.

22. The method of claim 21, wherein the one or more precursor compounds includes one or more precursor compounds that include F_x, wherein each F is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb each x is independently a non-zero integer, and wherein each of A, B, C, D, E, and F are different.

23. The method of claim 22, wherein the one or more precursor compounds includes one or more precursor compounds that include G_x, wherein each G is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, F, and G are different.

24. The method of claim 23, wherein depositing a channel includes a step for vaporizing the precursor composition to form a vaporized precursor composition, and depositing the vaporized precursor composition using a physical vapor deposition technique including one or more of dc reactive sputtering, rf sputtering, magnetron sputtering, ion beam sputtering.

25. A method of manufacturing a semiconductor device, comprising:
providing a drain electrode;
providing a source electrode;

a step for providing a precursor composition including one or more precursor compounds that include A_x, one or more precursor compounds that include B_x, and one or more precursor compounds that include C_x, wherein each A is selected from the group of Zn, Cd, each B is selected from the group of Ga, In, each C is selected from the group Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, and C are different;

a step for depositing a channel including depositing the precursor composition to form a multicomponent oxide from the precursor composition to electrically couple the drain electrode and the source electrode;

providing a gate electrode; and

providing a gate dielectric positioned between the gate electrode and the channel.

26. The method of claim 25, wherein the step for depositing a channel includes a step for vaporizing the precursor composition to form a vaporized precursor composition, and depositing the vaporized precursor composition using a physical vapor deposition technique including one or more of dc reactive sputtering, rf sputtering, magnetron sputtering, ion beam sputtering.

27. The method of claim 25, wherein the step for depositing a channel includes an ink-jet deposition technique.

28. The method of claim 25, wherein providing the source, the drain, and the gate electrodes includes providing a substantially transparent form of the source, the drain, and the gate electrodes.

29. The method of claim 25, wherein the one or more precursor compounds includes one or more precursor compounds that include D_x, wherein each D is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, and D are different.

30. The method of claim 29, wherein the one or more precursor compounds includes one or more precursor compounds that include E_x, wherein each E is

selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, D, and E are different.

31. The method of claim 30, wherein the one or more precursor compounds includes one or more precursor compounds that include F_x, wherein each F is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, and F are different.

32. The method of claim 31, wherein the one or more precursor compounds includes one or more precursor compounds that include G_x, wherein each G is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, F, and G are different.

33. A semiconductor device formed by the steps, comprising:

providing a drain electrode;

providing a source electrode;

providing a precursor composition including one or more precursor compounds that include A_x, one or more precursor compounds that include B_x, and one or more precursor compounds that include C_x, wherein each A is selected from the group of Zn, Cd, each B is selected from the group of Ga, In, each C is selected from the group Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, and C are different;

depositing a channel including the precursor composition to form a multicomponent oxide from the precursor composition to electrically couple the drain electrode and the source electrode;

providing a gate electrode; and

providing a gate dielectric positioned between the gate electrode and the channel.

34. The semiconductor device of claim 33, wherein the one or more precursor compounds includes one or more precursor compounds that include D_x, wherein each D is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, and D are different.

35. The semiconductor device of claim 34, wherein the one or more precursor compounds includes one or more precursor compounds that include E_x, wherein each E is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, D, and E are different.

36. The semiconductor device of claim 35, wherein the one or more precursor compounds includes one or more precursor compounds that include F_x, wherein each F is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, and F are different.

37. The semiconductor device of claim 36, wherein the one or more precursor compounds includes one or more precursor compounds that include G_x, wherein each G is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, F, and G are different.

38. The semiconductor device of claim 37, wherein depositing the channel includes vaporizing the precursor composition to form a vaporized precursor composition, and depositing the vaporized precursor composition using a physical vapor deposition technique including one or more of dc reactive sputtering, rf sputtering, magnetron sputtering, ion beam sputtering.

39. The semiconductor device of claim 33, wherein providing the source, the drain, and the gate electrodes includes providing a substantially transparent form of the source, the drain, and the gate electrodes.

40. The semiconductor device of claim 33, wherein providing the precursor composition includes providing a liquid form of the precursor composition.

41. The semiconductor device of claim 40, wherein depositing the channel includes an ink-jet deposition technique when the precursor composition includes the liquid form.

42. A method for operating a semiconductor device, comprising:

providing a semiconductor device that includes a source electrode, a drain electrode, and a channel to electrically couple the source electrode and the drain electrode, a gate electrode separated from the channel by a gate dielectric, wherein the channel includes a multicomponent oxide selected from at least one metal cation from group 12, at least one metal cation from group 13, and at least one metal cation from group 14, wherein group 12 cations include Zn and Cd, group 13 cations include Ga and In, group 14 cations include Ge, Sn, and Pb, wherein each component in the multicomponent oxide is different; and

applying a voltage to the gate electrode to effect a flow of electrons through the channel.

43. The method of claim 42, wherein operating the semiconductor device includes using the semiconductor device as a switch in a display device.

44. The method of claim 42, wherein operating the semiconductor device includes conducting electrons through the channel in a linear region of operation.

45. A display device, comprising:

a plurality of pixel devices configured to operate collectively to display images, where each of the pixel devices includes a semiconductor device configured to control light emitted by the pixel device, the semiconductor device including:

a drain electrode;

a source electrode;

a channel contacting the drain electrode and the source electrode, wherein the channel includes one or more compounds of the formula $A_xB_xC_xO_x$, wherein each A is selected from the group of Zn, Cd, each B is selected from the group of Ga, In, each C is selected from the group

Ge, Sn, Pb, each O is atomic oxygen; each x is independently a non-zero integer, and wherein each of A, B, and C are different;

a gate electrode; and

a gate dielectric positioned between the gate electrode and the channel and configured to permit application of an electric field to the channel.

46. The display of claim 45, wherein the one or more compounds of the formula $A_xB_xC_xO_x$ includes an atomic composition of ratio A:B:C, wherein A, B, and C are each in a range of about 0.025 to about 0.95.

47. The display of claim 45, wherein the source, the drain, and the gate electrodes include a substantially transparent material.

48. The display of claim 45, wherein the one or more compounds of the formula $A_xB_xC_xO_x$ includes D_x, to form a compound of the formula $A_xB_xC_xD_xO_x$, wherein each D is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, and D are different.

49. The display of claim 48, wherein the one or more compounds of the formula $A_xB_xC_xD_xO_x$ includes an atomic composition of ratio A:B:C:D, wherein A, B, C, and D are each in a range of about 0.017 to about 0.95.

50. The display of claim 48, wherein the one or more compounds of formula $A_xB_xC_x$ D_xO_x includes E_x to form a compound of the formula $A_xB_xC_xD_xE_xO_x$, wherein each E is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, D, and E are different.

51. The display of claim 50, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xO_x$ includes an atomic composition of ratio A:B:C:D:E, wherein A, B, C, D, and E are each in a range of about 0.013 to about 0.95.

52. The display of claim 50, wherein the one or more compounds of formula $A_xB_xC_x$ $D_xE_xO_x$ includes F_x to form a compound of the formula $A_xB_xC_xD_xE_xF_xO_x$, wherein each F is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, and F are different.

53. The display of claim 52, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xF_xO_x$ includes an atomic composition of ratio A:B:C:D:E:F, wherein A, B, C, D, E, and F are each in a range of about 0.01 to about 0.95.

54. The display of claim 52, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xF_xO_x$, includes G_x to form a compound of the formula $A_xB_xC_xD_xE_xF_x$ G_xO_x, wherein each G is selected from the group of Zn, Cd, Ga, In, Ge, Sn, Pb, each O is atomic oxygen, each x is independently a non-zero integer, and wherein each of A, B, C, D, E, F, and G are different.

55. The display of claim 54, wherein the one or more compounds of the formula $A_xB_xC_xD_xE_xF_xG_xO_x$ includes an atomic composition of ratio A:B:C:D:E:F:G, wherein A, B, C, D, E, F, and G are each in a range of about 0.0085 to about 0.95.

56. The display of claim 56, wherein the channel includes one of an amorphous form, a single-phase crystalline form, and a mixed-phase crystalline form.

57. A semiconductor device, comprising:

a drain electrode;

a source electrode;

a channel contacting the drain electrode and the source electrode, wherein the channel includes one or more of a metal oxide including zinc-gallium-germanium, zinc-gallium-tin, zinc-gallium-lead, cadmium-gallium-germanium, cadmium-gallium-tin, cadmium-gallium-lead, zinc-indium-germanium, zinc-indium-tin, zinc-indium-lead, cadmium-indium-germanium, cadmium-indium-tin, cadmium-indium-lead; and

a gate dielectric positioned between the gate electrode and the channel.

58. The semiconductor device of claim 57, wherein the metal oxide includes one or more of zinc-gallium-germanium-oxide, zinc-gallium-tin-oxide, zinc-gallium-lead-oxide, cadmium-gallium-germanium-oxide, cadmium-gallium-tin-oxide, cadmium-gallium-lead-oxide, zinc-indium-germanium-oxide, zinc-indium-tin-oxide, zinc-indium-lead-oxide, cadmium-indium-germanium-oxide, cadmium-indium-tin-oxide, cadmium-indium-lead-oxide.

59. The semiconductor device of claim 58, wherein the metal oxide includes an atomic composition of A:B:C, wherein A, B, and C are each in a range of about 0.025 to about 0.95.

60. The semiconductor device of claim 57, wherein the metal oxide includes one or more of zinc-gallium-germanium-tin oxide, cadmium-gallium-germanium-tin oxide, zinc-indium-germanium-tin oxide, cadmium-indium-germanium-tin oxide, zinc-gallium-germanium-lead oxide, cadmium-gallium-germanium-lead oxide, zinc-gallium-tin-lead oxide, cadmium-gallium-tin-lead oxide, zinc-indium-germanium-lead oxide, cadmium-indium-germanium-lead oxide ,zinc-indium-tin-lead oxide, cadmium-indium-tin-lead oxide, zinc-gallium-indium-germanium oxide, cadmium-gallium-indium-germanium oxide, zinc-gallium-indium-tin oxide, cadmium-gallium-indium-tin oxide, zinc-gallium-indium-lead oxide cadmium-gallium-indium-lead oxide, zinc-cadmium-gallium-germanium oxide, zinc-cadmium-gallium-tin oxide, zinc-cadmium-gallium-lead oxide, zinc-cadmium-indium-germanium oxide, zinc-cadmium-indium-tin oxide, zinc-cadmium-indium-lead oxide.

61. The semiconductor device of claim 60, wherein the metal oxide includes an atomic composition of A:B:C:D, wherein A, B, C, and D are each in a range of about 0.017 to about 0.95.

62 The semiconductor device of claim 57, wherein the metal oxide includes one or more of zinc-cadmium-gallium-indium-germanium oxide, zinc-cadmium-gallium-indium-tin oxide, zinc-cadmium-gallium-indium-lead oxide, zinc-

gallium-germanium-tin-lead oxide, zinc-indium-germanium-tin-lead oxide, cadmium-gallium-germanium-tin-lead oxide, cadmium-indium-germanium-tin-lead oxide, zinc-cadmium-gallium-germanium-tin oxide, zinc-cadmium-indium-germanium-tin oxide, zinc-cadmium-gallium-germanium-lead oxide, zinc-cadmium-indium-germanium-lead oxide, zinc-cadmium-gallium-tin-lead oxide, zinc-cadmium-indium-tin-lead oxide, zinc-gallium-indium-germanium-tin oxide, cadmium-gallium-indium-germanium-tin oxide, zinc-gallium-indium-germanium-lead oxide, cadmium-gallium-indium-germanium-lead oxide, zinc-gallium-indium-tin-lead oxide, cadmium-gallium-indium-tin-lead oxide.

63. The semiconductor device of claim 62, wherein the metal oxide includes an atomic composition of A:B:C:D:E, wherein A, B, C, D, and E are each in a range of about 0.013 to about 0.95.

64. The semiconductor device of claim 57, wherein the metal oxide includes one or more of zinc-cadmium-gallium-indium-germanium-tin oxide, zinc-cadmium-gallium-indium-germanium-lead oxide, zinc-cadmium-gallium-indium-tin-lead oxide, zinc-cadmium-gallium-germanium-tin-lead oxide, zinc-cadmium-indium-germanium-tin-lead oxide, zinc-gallium-indium-germanium-tin-lead oxide, cadmium-gallium-indium-germanium-tin-lead oxide.

65. The semiconductor device of claim 64, wherein the metal oxide includes an atomic composition of A:B:C:D:E:F, wherein A, B, C, D, E, and F are each in a range of about 0.01 to about 0.95.

66. The semiconductor device of claim 57, wherein the metal oxide includes one or more of zinc-cadmium-gallium-indium-germanium-tin-lead oxide.

67. The semiconductor device of claim 66, wherein the metal oxide includes an atomic composition of A:B:C:D:E:F:G, wherein A, B, C, D, E, F, and G are each in a range of about 0.0085 to about 0.95.